USGS
science for a changing world

75
Re
$[Xe]6s^24f^{14}5d^5$
186.2

USGS Mineral Resources Program

Rhenium—A Rare Metal Critical to Modern Transportation

As part of a broad mission to conduct research and provide information on nonfuel mineral resources, the U.S. Geological Survey (USGS) supports science to understand

- *How and where rhenium resources form and concentrate in the Earth's crust*
- *How rhenium resources interact with the environment to affect human and ecosystem health*
- *What the trends are in rhenium supply and demand in domestic and international markets*
- *Where undiscovered rhenium resources might be found*

Why is this information important? Read on to learn about rhenium and the important role it plays in the national economy, in national security, and in the lives of Americans every day.

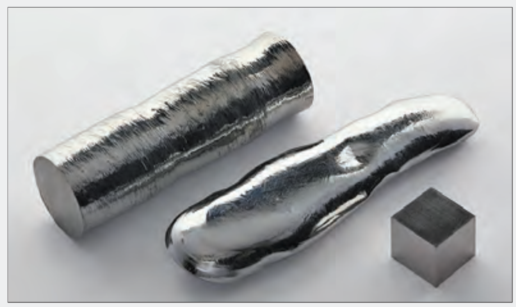
Rhenium is a silvery-white, metallic element with an extremely high melting point (3,180 degrees Celsius) and a heat-stable crystalline structure, making it exceptionally resistant to heat and wear. Since the late 1980s, rhenium has been critical for superalloys used in turbine blades and in catalysts used to produce lead-free gasoline.

One of the rarest elements, rhenium has an average abundance of less than one part per billion in the continental crust. Rhenium was the last stable, naturally occurring element discovered. Although its existence was predicted in 1871—Russian chemist Dmitri Mendeleev noted two vacant slots below manganese on the periodic table of elements—rhenium was not isolated until 1925, when German chemists Walker Noddack, Ida Tacke, and Otto Berg detected it in platinum ore.

Rhenium rarely occurs as a native element or as its own sulfide mineral—rheniite (ReS_2)—and often occurs as a substitute for molybdenum in molybdenite (MoS_2). Most extracted rhenium is a byproduct of copper mining, with about 80 percent recovered from flue dust during the processing of molybdenite concentrates from porphyry copper deposits.

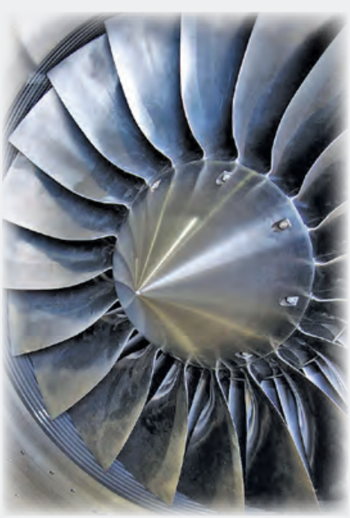
How Do We Use Rhenium?

Over 80 percent of the rhenium consumed worldwide is used in superalloy production. These nickel-base alloys contain either 3 or 6 percent rhenium, which is critical to the manufacture of turbine blades for jet aircraft engines and industrial gas turbine engines. The high-temperature properties of rhenium allow turbine engines to be designed with finer tolerances and operate at temperatures higher than those of engines constructed with other materials. These properties allow prolonged engine life, increased engine performance, and enhanced operating efficiency.



A single crystal bar of high purity (99.999%) rhenium, a remelted rhenium bar, and a 1-cm³ rhenium cube. Photograph by Alchemist-hp (http://commons.wikimedia.org/wiki/File:Rhenium_single_crystal_bar_and_1cm3_cube.jpg)

The other major use of rhenium, which accounts for about 10 percent of worldwide rhenium consumption, is in platinum-rhenium catalysts. The petroleum industry uses platinum-rhenium catalysts to produce high-octane, lead-free gasoline. These catalysts boost the octane level of refined gasoline and improve refinery efficiency. Secondary applications of rhenium include the manufacture of electrical contact points, flashbulbs, heating elements, vacuum tubes, X-ray tubes and targets, and uses in various medical procedures.



Nickel-base superalloys used in the turbine blades of jet engines are the most common use of rhenium. Photograph by Tony Hisgett from Birmingham, United Kingdom. (Available at http://commons.wikimedia.org/wiki/File:Inlet_of_jet_engine.jpg)

Where Does Rhenium Come From?

Nearly all primary (not recycled) rhenium is a byproduct of copper mining. Rhenium resources, largely contained in porphyry copper deposits, supply about 80 percent of the rhenium produced by mining. Molybdenite, which commonly contains between 100 and 3,000 parts per million rhenium, is the principal source of rhenium in porphyry copper deposits. Porphyry copper ores typically contain less than 0.5 grams per metric ton rhenium, but rhenium production is feasible because of the large ore tonnage processed (hundreds of millions to billions of metric tons [1,000 kilograms per metric ton]), the presence of sufficient molybdenite to make its recovery economically practical, and the presence of specialized facilities that allow rhenium recovery from molybdenite.

Sediment-hosted stratabound copper deposits in Kazakhstan (sandstone-type) and Poland (Kupferschiefer ["copper schist"] or reduced facies-type) supply most of the remaining rhenium produced by mining. Small amounts of rhenium are recovered by processing roll-front-type sandstone uranium ores in Kazakhstan and elsewhere. The residence site of rhenium in these copper deposits is poorly understood. Much of the rhenium in Kazakhstan's sandstone-hosted deposits may be in dzhezkazganite, a complex mineral containing rhenium, molybdenum, copper, and lead, whereas rhenium in Poland's Kupferschiefer deposits may be contained in castaingite, a copper-rich molybdenite.

Rhenium is recovered from gases released during the roasting of molybdenite concentrates from porphyry copper deposits and of copper sulfide ores from sediment-hosted stratabound copper deposits. During the roasting process, rhenium is oxidized and passed up a flue stack with sulfur gases. Scrubbing of the flue dusts and gases produces sulfuric acid and other fluids that contain dissolved rhenium. The rhenium is ultimately precipitated from these fluids as ammonium perrhenate (NH_4ReO_4), a white powder that is the principal form in which rhenium is marketed.

U.S. Department of the Interior
U.S. Geological Survey

Fact Sheet 2014–3101
April 2015

Rhenium Supply and Demand Worldwide

Worldwide mine production of rhenium in 2012 was 52,600 kilograms (kg); about 27,000 kg were produced from porphyry copper mines in Chile (Polyak, 2013). Rhenium is also produced from porphyry copper deposits in Peru, the United States, Kazakhstan, Uzbekistan, Russia, and Armenia. The United States' rhenium production in 2012 was 7,900 kg (Polyak, 2013).

Rhenium resources in the United States are located in Arizona and Utah, with smaller resources found in Montana, New Mexico, and Nevada. An unmined deposit in Alaska contains a large inferred rhenium resource. Identified U.S. rhenium resources are estimated to be about 5 million kg, and the identified rhenium resources for the rest of the world are approximately 6 million kg (Polyak, 2013). The largest identified rhenium resources outside the United States are in Chile, Peru, Canada, Poland, and Kazakhstan.

Rhenium recycling processes continue to develop. Because the turbine blade life cycle in jet engines is approximately 10 years, significant quantities of second-generation blades, which contain 3 percent rhenium, are accumulating. Technological advances will eventually allow second-generation blades to be recycled so that recovered rhenium can be used to manufacture third-generation blades, potentially reducing primary rhenium requirements by about 50 percent. The number of companies that process molybdenum-rhenium scrap and tungsten-rhenium scrap continues to grow, especially in the United States and Germany. In addition, spent platinum-rhenium catalysts are recycled, and the rhenium is recovered.

Molybdenite is a gray, metallic mineral found in veins and disseminated in most porphyry copper deposits. It commonly contains hundreds to thousands of parts per million of rhenium as a substitute for molybdenum in its crystalline structure and is the main source of rhenium. Photograph by David John.

World consumption of rhenium was estimated at 50,000 to 55,000 kg per year in 2012, and it is estimated that worldwide rhenium consumption will increase to about 71,500 kg by 2015. The United States is the largest consumer of rhenium with an apparent consumption of 48,000 kg in 2012. In the United States, nearly 80 percent of consumed rhenium is imported, mostly from Chile and Kazakhstan.

Did you know... ***Rhenium is named for the Rhine River, which comes from the Latin word, Rhenus***

How Do We Ensure Adequate Supplies of Rhenium for the Future?

The United States is unlikely to meet its rhenium requirements with domestic resources. Although there are substantial, proven rhenium reserves in porphyry copper deposits in the United States, special facilities are required to extract rhenium from the molybdenite concentrates recovered from these deposits. In the United States, only one molybdenum concentrate roasting facility is equipped to recover rhenium, and although a second plant is under construction and could increase U.S. production by about 50 percent, the potential rhenium production from these plants is far less than current U.S. consumption. Therefore, it is likely that imports will continue to supply most of the rhenium consumed in the United States.

To determine where future rhenium supplies might be located, USGS scientists study how and where rhenium resources are concentrated in Earth's crust and use that knowledge to assess the likelihood that undiscovered rhenium resources exist. Techniques used to assess mineral resources were developed by the USGS to support the stewardship of Federal lands and better evaluate mineral resource availability in a global context. The USGS also compiles statistics and information on the worldwide supply, demand, and flow of rhenium. These data inform U.S. national policymaking.

The Butte porphyry copper-molybdenum deposit is mined in the Continental Pit. Rhenium is recovered from molybdenite concentrates produced from the Butte deposit. Porphyry copper deposits are the world's largest source of rhenium. Photograph by David John.

Did you know... ***Rhenium has 28 isotopes. ^{188}Re and ^{186}Re are short-lived (90 and 17 hours, respectively) radioactive isotopes used to treat liver and bone cancer and arthritis***

For More Information

- On production and consumption of rhenium: http://minerals.usgs.gov/minerals/pubs/commodity/rhenium/
- On porphyry copper deposit models: http://pubs.usgs.gov/sir/2010/5070/b/

Reference Cited

Polyak, D.E., 2013, Rhenium [advance release], *in* Metals and minerals: U.S. Geological Survey, Minerals Yearbook 2012, v. I, 5 p., accessed August 12, 2014, at http://minerals.usgs.gov/minerals/pubs/commodity/rhenium/myb1-2012-rheni.pdf.

The USGS Mineral Resources Program is the principal Federal provider of research and information on rhenium and other nonfuel mineral resources.

For more information, please contact:

Mineral Resources Program Coordinator
U.S. Geological Survey
913 National Center
Reston, VA 20192
Telephone: 703–648–6100
Fax: 703–648–6057
Email: minerals@usgs.gov
Home page: http://minerals.usgs.gov

75
Re
[Xe]6s^{2}4f^{14}5d^5
186.2

Text prepared by David John.

ISSN 2327–6932 (online)
http://dx.doi.org/10.3133/fs20143101